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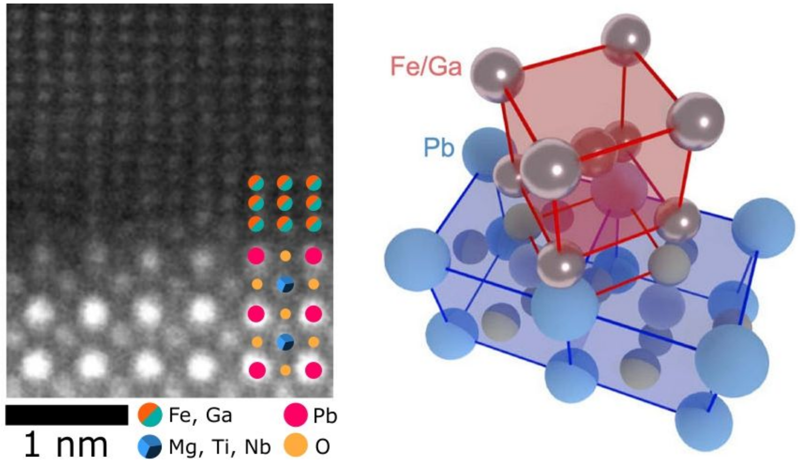
User Research - 2021

Beyond *Terfenol-D*

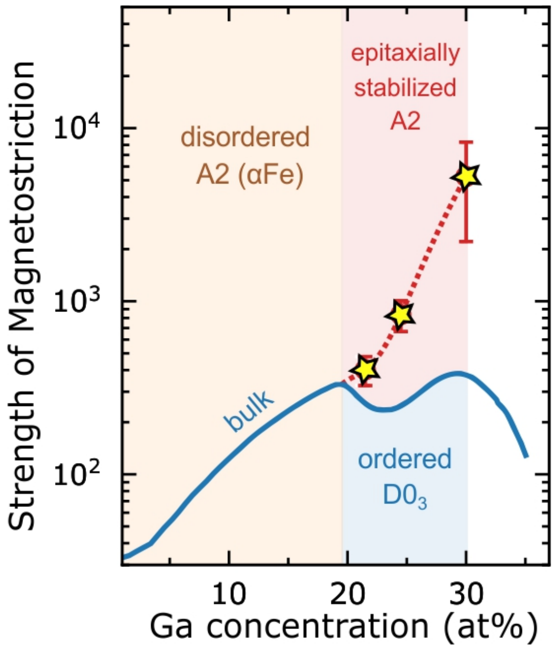
J.T. Heron, E. Kioupakis, R. Hovden, University of Michigan + 14 other institutions (including Intel)

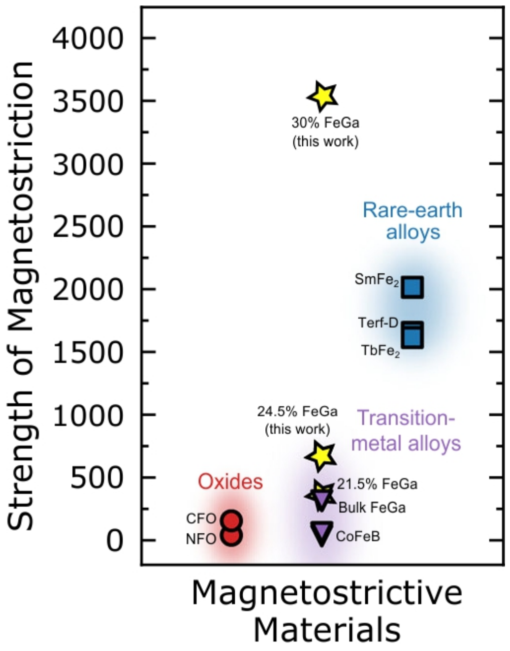
For nearly 50 years, Terfenol-D ($Tb_xDy_{1-x}Fe_2$) has reigned as the material for which an applied magnetic field results in the greatest change in shape, a property known as magnetostriction. A distant second to Terfenol-D is Galfenol ($Fe_{1-x}Ga_x$), the best magnetostrictor free of rare-earth elements.

When a magnetostrictive material is combined with a piezoelectric material, the resulting composite enables electrical control of magnetism at room temperature. Such composites were first made by gluing a high-performance piezoelectric (*e.g.*, PMN-PT) to a magnetostrictor.



P.B. Meisenheimer *et al.* Nat. Commun. **12**, 2757 (2021).





PARADIM user John Heron wanted to eliminate the glue in such a composite to achieve better coupling and higher performance. So, he came to PARADIM to make an atomically abrupt epitaxial composite using PMN-PT as a single-crystal substrate onto which he deposited Galfenol. Not only did he achieve epitaxy, but the epitaxy enabled him to stabilize the high-performance A2 magnetostrictive phase of Galfenol to higher gallium concentrations than ever before achieved. Importantly, his measurements showed that the magnetostriction in this metastable A2 phase continued to increase—becoming **10x higher than bulk Galfenol and nearly twice as high as Terfenol-D, *i.e.*, a new record magnetostrictor has been born!** The composites utilizing this record magnetostrictor also have superb performance and calculations indicate that when optimally scaled they will provide non-volatile functionality with switching energies of ~80 aJ/bit. These epitaxial composites are thus relevant to beyond CMOS devices.